HISTORY, ACHIEVEMENTS AND THE FUTURE OF SCICEX

The Science Ice Exercise Program

With the end of the Cold War in 1989, the military significance of the Arctic Ocean, where submarines of the superpowers had played â€˜cat and mouseâ€™ for decades, dramatically decreased. The lessening of the classified naval operations in the Arctic prompted a small group of Arctic Ocean researchers to approach the US Navyâ€™s submarine force and ultimately convince the service that it should (and could) provide to the civilian science community the services of a dedicated nuclear submarine for a series of research cruises to the Arctic Ocean with scientists onboard. What resulted was a unique and successful co-operative programme that truly opened the door to increasing dramatically our knowledge and understanding of the worlds most poorly understood ocean.

The retirement of the USS *L Mendel Rivers* in 2001, marked the last of the United States Navyâ€™s workhorse, â€˜fully Arctic-capableâ€™ nuclear submarinesâ€™the SSN-637 Class - and with them, a significant research capability both for the U.S. Navy and Arctic science community. This class of submarines during its 30+ years of operation defined the Navyâ€™s Arctic war fighting capability. However, to the civilian science community, it was an invaluable platform for the submarine Science Ice Exercise (SCICEX) program, a series of six dedicated cruises that completely revised our understanding of the Arctic Ocean and the ocean bottom.

Gathering Support for Data Collection
Nuclear submarines began operating under the Arctic Ocean sea ice in 1957 with the deployment of the USS Nautilus. For the next 20 years or so, all submarine deployments to the Arctic were classified and rarely discussed outside Navy circles. Perhaps the most significant early public data release was in 1976, when the USS Gurnard collected ice profile data to support the Arctic Ice Dynamics Joint Experiment.
In the 1980s, stimulated by the Cold War, submarine deployments to the Arctic increased. Occasionally a civilian researcher would be allowed to receive data to fill a specific Navy science need. Navy technicians collected those data. No civilians rode submarines to the Arctic.
In the late 1980â€™s environmental data, especially that in the Arctic, took on increasing importance. The U.S. Arctic Research Commission (USARC) took advantage of this interest and encouraged the U.S. Navy to conduct civilian science from submarines. While the Navy was initially unenthusiastic, a waning Cold War and concomitant decrease in the need for warfare-related Arctic R&D justified performing pure civilian science.
Early in 1989 with prodding from the USARC, the Navy agreed to collect Arctic Ocean water samples for a civilian researcher. The results of this small-scale data collection effort also benefited the Navy by providing new understanding of the Arctic Oceanâ€™s currents. The success of this venture convinced the USARC and the National Science Foundation (NSF) that to accomplish the needed Arctic Ocean research, dedicated cruises by submarines would be required. The Navy was not interested such a programme.

SCICEX Is Initiated
However, this resistance was short-lived. By 1992, Navy interest in the project began to emerge. Encouraged by the USARC, the Navy committed to a â€˜trialâ€™ SCICEX cruise in January 1993 under the guidance of 12 prominent Arctic Ocean scientists and the U.S. Navyâ€™s Arctic Submarine Laboratory (ASL). The cruise took place in September and October 1993 aboard the USS *Pargo*. It was a watershed event.
Based on the success of the 1993 cruise, a Memorandum of Agreement (MOA) was prepared and signed on August 1994 between the Navy and four Federal science agencies. It ensured a series of dedicated cruises. The first SCICEX cruise departed from Pearl Harbor, Hawaii, aboard the USS *Cavalla* in March 1995. It concluded in May.
In the period between the *Pargo* and *Cavalla* cruises, the Navy announced that it was increasing the unclassified (publicly releasable) submarine operating depth from 400 to 800 feet and the unclassified speed from 20 to 25 knots. These unprecedented changes in Navy security were the first since World War II and allowed unclassified data collection over the full extent of the surface-mixed layer in the Arctic Ocean. Not only was access to data improved by its simplified, public release, but also the Navy agreed to announce the name of the vessel and the sailing date for cruises well before the start of the exercise. This simplified planning greatly.

During the SCICEX program, the science community benefited from an enormous infusion of data. Each submarine was fitted with between eight and 13 different data collection systems. (Table 1) On the last two cruises, the USS *Hawkbill* carried the Seafloor Characterization and Mapping Pods (SCAMP), the largest and most expensive civilian research system ever installed aboard a U.S. Navy submarine.
The SCAMP system was a purpose-built geophysical system consisting of four subsystems: a swath bathymetric side-scan sonar, a high-resolution sub-bottom profiler, a data acquisition and quality control system and the Bell BGM-3 gravimeter. The bathymetric swath sonar had 270 transducers in a 20â€x3â€ neutrally buoyant pod mounted on the keel of the submarine. The profiler was in a separate keel mounted pod forward of the swath sonar. Lamont Doherty Earth Observatory, The Applied Physics Lab at Johns Hopkins University, two major defense contractors and four Navy commands combined to design, build, install and operate this unique and marvellously performing system. A sample of the product of the bathymetric side-scan sonar is shown in Figure 1.

The Arctic Ocean in a Whole New Light
The SCICEX submarines collectively spent 211 days and cruised over 95,000km collecting data under the sea ice (Figure 2). Not only was extensive data collected, but notable and unique scientific discoveries were made, all of which would have been impossible without the submarine as a science platform. These accomplishments included:

- superior access to the Arctic Ocean - all seasons, all weather, all areas - the submarine is quieter, more stable, and five times faster than any Arctic science platform ever employed
- six synoptic views of the ocean with co-registered data sets
- confirmation of significant warming of the core Atlantic water entering the Arctic and significant movement of the Atlantic/Pacific front into the western Arctic basin
- determination that the Arctic sea ice pack has thinned by nearly 35 percent in the last four decades
- sub-bottom chirp-sounder profiles heralded as the highest quality ever collected.
- over 25 million new soundings from the Chukchi Cap, Northwind Rise, Lomonosov Ridge and Nansen-Gakkel Ridge dwarfing the existing one million, all-source bathymetry database and enabling a new and much more accurate picture of the Arctic Ocean bottom
- irrefutable evidence, provided by SCAMP, of the existence of a massive Arctic Ocean Pleistocene ice sheet, the presence of huge icebergs, and sea floor volcanism. This evidence will have great impact on reconstructing the earthâ€™s geologic and climatic history, and, more importantly, modelling the earthâ€™s future climate.

Clearly the SCICEX cruises motivated serious revisions in what science had previously thought of the Arctic.
However, despite a new understanding of the Arctic, prospects for continuing regular, dedicated cruises are dim. At the core of SCICEXâ€™s future is the retirement of all SSN-637 Class submarines. The science community, excited by the new discoveries in the Arctic, seeks more information. The Navy understands the scientific need but is realistic about the availability of its assets for dedicated cruises. The submarine force is now one half the size of the force when SCICEX started and more missions than the submarine force can fulfil are being assigned by military commanders.
The Navy did offer to consider conducting unannounced, ad-hoc data collection operations in the Arctic if time was available during military deployments. There would be no civilians aboard. Data would be collected by Navy technicians, using a priority list established in advance by a civilian science committee. Since 1999, three submarines have collected data over 9,000km of track. This is small when compared to dedicated cruises, but it is better than no data. A good dialogue exists between the Navy and the science community.
Meanwhile, the science community has looked to other potential means to get the Arctic Ocean data they believe is essential. The air-independent submarines of other countries, developmental/experimental undersea platforms, autonomous underwater vehicles and ice camps all have been examined as possible alternatives. None possesses the broad capabilities of a nuclear submarine.
In conclusion, one must note that from six SCICEX deployments, the total body of Arctic Ocean data has been estimated to have doubled. While the U.S. Navy has been uniformly helpful, the advantages of employing an SSN for science have not yet been fully exploited. The exciting discoveries made during the 211 days of dedicated data collection, particularly from the SCAMP seafloor mapping system, are a strong motivation to future co-operative use of dedicated nuclear submarines for Arctic science.